EFFECT OF PHYSICAL TRAINING ON QUANTITATIVE ULTRASOUND PARAMETERS OF THE CALCANEUS: A COMPARISON BETWEEN GYMNASTS AND SWIMMERS

FİZİKSEL ANTRENMANLARIN KANTİTATİF TOPUK ULTRASON PARAMETRELERİNE ETKİSİ: JİMNASTİK VE YÜZÜCÜLER ARASINDA BİR KIYASLAMA

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SUMMARY

The aim of this study was to investigate the difference of calcaneal quantitative ultrasound (QUS) measurements between competitive prepubertal girl athletes. Twelve gymnasts and 13 swimmers wer included in the study. Gymnasts had trained 23-30 h per week and swimmers had trained 14-16 h p week for at least 3 years before starting the study. Body weight, height, body mass index and percent bod fat were measured. QUS parameters of the calcaneus were evaluated using Sahara Clinical Bor Sonometer. Diet assessment and daily intake of miligrams of calcium was obtained by a food frequen questionnaire. No statistically significant difference regarding QUS measurements between gymnasts ar swimmers was observed in this study; but after adjusting for body weight, with covariance analyses, w found significant difference in calcaneal QUS measurements between gymnasts and swimmers, with high values for gymnasts. There were no significant differences between groups for any of the dietary variables In conclusion physical activity in childhood could be an important factor in bone mineral acquisition; could provide protection against risks of osteoporosis in later life.

ÖZET

Bu çalışmanın amacı, yarışçı düzeyindeki prepubertal kız sporcuların topuk ultrason ölçümlerinin farkla araştırmaktı. 12 jimnastikçi ve 13 yüzücü sporcu bu çalışmaya dahil edildi. En az 3 yıldır, jimnastikçi haftada 23-30 saat, yüzücüler 14-16 saat antrenman yapmaktaydılar. Sporcuların boyları ve kilola ölçüldü, vücut kitle indeksi ve vücut yağ oranları hesaplandı. Topuk ultrason ölçümleri Sahara Clinical B Sonometer ile gerçekleştirildi. Sporcuların diyet durumları ve diyetle aldıkları günlük kalsiyum miktarl özel olarak hazırlanmış bir anket formu ile değerlendirildi. Topuk ultrason ölçümleri arasında iki gı arasında fark bulunmazken, vücut ağırlığının kovariant olarak kullanıldığı kovaryans analizinc jimnastikçiler lehine daha yüksek ölçüm değerleri saptanmıştır. Diyet açısından iki grup arasında belir bir fark bulunmamıştır. Özetle; çocukluktaki fiziksel aktiviteler, kemik mineral kazanımı açısından öne bir faktör olabilir; bu durum ilerki yaşamda osteoporoz riskine karşı koruyucu olabilir.

INTRODUCTION

The importance of physical activity during childhood as a determinant of adult peak bone mass has received increased attention during the past decade (1,2). The peak bone mass in early adulthood and the subsequent rate of bone loss are the main determinants of bone mass in later life (3).

Several recent studies have given strong evidence that 95-99 % of the peak bone mass is gained during the first decades of life (4,5)

Exercise, such as resistance training or weight-bearing activities like running or walking, seems to have an osteogenic effect on developing and maintaining bone mineral density (BMD) (6,7, 8).

Studies on athletes who perform different types of sports confirm that athletes involved in high impact weight-bearing activity (e.g.gymnastics) have greater site-specific BMD than athletes performing non-weight-bearing (9,10) or low-impact weight bearing sports (11).

Gymnastics is characterized by very high impacts through repeated jumps and body contacts with hard surfaces. There is no any weight-bearing activity during swimming, but strain owing to increased muscle contraction leads to increase mechanical loading on swimmers' skeleton.

The calcaneus is a weight- bearing bone consisting of approximately 90-95% trabecular bone which might be expected to show considerable response to loading.

The most common method for assessing BMD is x-ray densitometric techniques (DXA, SXA, DEXA.). Quantitative ultrasound (QUS) appears comparable to densitometry (12). QUS also provides a noninvasive assessment of bone, furthermore QUS is not ionizing electromagnetic radiation. The correlation of the results between sonographic measurements and DXA varies widely (r=0.29-0.87); this variation is largely related to the homogeneity of the study populations (13,14). Jaworski et al (15) found a high correlation (r=0.7-0.9) between sonographic measurements and BMD among children.

Studies among adult subjects have shown that athletes involved in various sports have greater QUS parameters of the calcaneus than non-athletic controls (16). There is a lack of data on the relationship between ultrasound measurements and exercise in children (17).

The purpose of the present investigation was to compare the calcaneal QUS measurements of competitive prepubertal female gymnasts and swimmers. Another purpose was to investigate the relationships between calcium intake, physical activity level and the parameters of calcaneal ultrasound.

METHOD

Subjects. 25 healthy prepubertal girls took part in this study. Subjects were engaged either in a sport requiring significant impact loading on the skeleton (gymnastics), or in a sport without impact loading (swimming). 12 elite gymnasts (12.00±1.7 years old) and 13 elite swimmers (11.41±1.16 years old) who had performed minimum 3 years of high level sport training (23-30 h per week for gymnasts 14-16 h per week for swimmers) were recruited from local clubs.

All subjects completed a medical questionnaire which included items relating to previous and current medical status, previous and current use of medications, and lifetime incidence of skeletal injury and fracture. All subjects were in good health and did not take any medications that are known to affect bone metabolism, and had no any metabolic disorders known to influence BMD or participation in physical activity. Diet assessment was obtained by a food frequency questionnaire. Subjects were requested to complete the questionnaire with the assistance of their mothers and study coordinator. Daily intake of miligrams of calcium was calculated from the food frequency questionnaire.

Anthropometric variables. Height was recorded without footwear, and subjects were instructed to stand erect and inhale during measurement. Body weight was measured while subjects were light clothing and no shoes. Body mass

index (BMI) was calculated as body weight in kg divided by body height (m) squared. Percent body fat was calculated from the measurements of skinfold.

Calcaneal ultrasound. Ultrasound parameters of the dominant heels were measured with the Hologic Sahara Clinical Bone Sonometer. BMD (g/cm^2) of the calcaneus, speed of sound (SOS; m/s), broadband ultrasound attenuation (BUA; dB/MHz) and quantitative ultrasound index (QUI) were obtained from the measurements.

Statistical Analyses. The statistical analyses were performed using SPSS (9.0 version) for Windows. The results of variables were reported as means ± standart deviations, and 95% confidence intervals were calculated for means of differences. Differences between gymnasts and swimmers were evaluated with the Mann-Whitney U Tests for unpaired observations. ANOVA with height and weight entered as co-varieties was also performed. Spearman's correlations were used to determine whether a relationship existed among the variables. All correlations were done not only for both groups but also using the combined data of the gymnasts and swimmers. Stepwise linear regression analysis determined the effect of the independent variables (age, height, weight, BMI, years of training, training time per week and diatary calcium intake) on the QUS parameters.

RESULTS

The subjects age and physical characteristics are summarized in Table 1. There was no statistical significant difference between groups regarding to the age and body height. Swimmers were heavier and had a higher BMI than gymnasts; gymnasts had a lower fat mass than swimmers ($p<0.05$). There was no statistically significant difference between groups regarding to the years of sport training. Mean sport training hour per week for gymnasts was statistically longer than in the swimmers (gym: 27.08±2.31; swim: 15.07±1.03, $p<0.05$). Daily calcium intake of the both groups was similar (gym: 1200 mg/day; swim: 1400 mg/day). There were no group differences for QUS parameters, but gymnasts had higher calcaneal SOS, QUI and BMD corrected for body weight than swimmers (Table 2). There was a significant positive correlation relationship among the QUS parameters (Table 3).

Table 1. Study populations

Characteristics	Gymnasts (n=12) Mean± SD	Swimmers (n=13) Mean± SD
Age (years)	12.00±1.70	11.41±1.16
Height (cm)	143.83±9.47	150.83±7.17
Weight (kg)	29.91±4.23	36.33±7.40*
Body Mass Index (kg/m^2)	14.82±1.48	15.85±2.11*
Body Fat (%)	8.92±0.73	10.70±2.20*

*p< 0.05

Table 2. Mean unadjusted values and adjusted values for body weight of the QUS parameters of the calcaneus in peripubertal gymnasts and swimmers

Variable	Gymnasts (n=12) Mean± SD	Swimmers (n=13) Mean± SD	Gymnasts (n=12) Mean± SD	Swimmers (n=13) Mean± SD
	(unadjusted values)		(adjusted values for body weight)	
BUA(dB/MHz)	71.27±11.10	68.59±16.74	75.70±3.91	63.89±3.91
SOS (m/s)	1575.46±16.97	1564.07±21.67	1578.39±5.84	1558.68±5.84*
QUI	104.16±10.50	98.38±15.09	107.18±3.81	94.24±3.81*
BMD (g/cm^2)	0.582±0.66	0.549±1.00	0.601±0.24	0.519±0.24*

BUA: broadband ultrasound attenuation; SOS: speed of sound; QUI:quantitative ultrasound index; BMD: bone mineral density.

*p< 0.05 (difference between gymnasts and swimmers regarding adjusted values for body weight).

Table 3. Correlation coefficient between calcaneal ultrasonographic parameters among gymnasts and swimmers

	Gymnasts (n=12)	Swimmers (n=13)	Total (n=25)
BUA vs. SOS	0.652*	0.834***	0.710***
BUA vs. QUI	0.865***	0.946***	0.880***
BUA vs. BMD	0.865***	0.910***	0.864***
SOS vs. QUI	0.945***	0.968***	0.938***
SOS vs.BMD	0.945***	0.980***	0.950***
QUI vs. BMD	1.000***	0.991***	0.988***

* p<0.05; *** p<0.001

Table 4. Correlation coefficient of calcaneal ultrasonographic parameters and age, height, weight, BMI, years o training, training time per week and dietary calcium intake in the peripubertal girls

Parameter	Age	Height	Weight	BMI	Years of training	Training time per week	Dietary calcium intake
BUA (dB/MHz)	0.285	0.314	0.94	-0.184	0.242	0.279	0.080
SOS (m/s)	0.014	-0.045	-0.278	-0.310	0.113	0.373	-0.033
QUI	0.148	0.112	-0.149	-0.317	0.164	0.380	0.018
BMD (g/cm^2)	0.156	0.115	-0.145	-0.313	0.161	0.350	0.023

In the whole group (n=25) QUS parameters did not correlated with the age, height, weight, BMI, years of training, training time per week and dietary calcium intake (Table 4). The body weight correlated significantly with the SOS, BUA and BMD values in the swimmers (r=0.585, 0.671 and 0.643 respectively) but not in gymnasts. By stepwise linear regression analysis, body weight accounted for 34% of the variations of the SOS, for 45% of the variations of the BUA and for 41% of the variations of the BMD of the swimmers.

DISCUSSION

This cross-sectional study was designed to compare the calcaneal QUS parameters between elite prepubertal gymnasts and elite prepubertal swimmers.

The finding of lower body fat among the gymnasts in this study is consisted with other reports on elite gymnasts (18,19). Swimmers were heavier and had higher percent body fat, however, there may be a sport- specific selection bias; while smaller girls may be more likely to success in gymnastics, fatty girls may be more likely to swim owing to increased buoyancy.

As would we expected, gymnasts spent significantly more time in training and engaged in weight bearing activity than swimmers. In this study, calcaneal QUS parameters normalized for body weight was significantly greater in the gymnasts than swimmers.

There have been a number of investigations about BMD in athletes involved in weight bearing activities (9-11,18-20) Majority of these studies have included adolescent and adult populations and have reported results of DXA measurements in the total body the lumbar spine and the hip. The present study compared calcaneal BMD in preadolescent girls who involved in high impact loading of gymnastic training and nonweightbearing activity of swimming training.

Studies of college-aged gymnasts have reported positive associations between high impact loading and BMD (20,21). In these studies it was also found that gymnasts had significantly greater hip and spine BMD after adjustment for covariance of body mass (19,20).

Generally, moderate correlations (in vivo) between QUS parameters and bone mineral

density measured by DXA, dual photon absorptiometry and single photon absorptiometry from several skeletal sites have been reported (22,23,24). QUS also has been shown to predict hip fractures independently of BMD of the hip and spine (25,26). In several studies on children, QUS seems to correlate with the x-ray measurements as for adults (27,28). In a recent study by Sunberg M et al (14), QUS measurements of the calcaneus in children show similar results as for adult regarding the correlations with DXA and SXA. In addition, the QUS values were found to have the same relationship with age as DXA and SXA in that study.

In our study on prepubertal girl athletes it appears that QUS can discriminate the differences of the QUS parameters of two groups.

The effect of physical activity on bone is a result of either strain on the skeleton from muscle contraction or from external mechanical forces (29). Our finding showing lower BMD among the swimmers suggested that muscle contraction during swimming appears not to be related to BMD. Our results also suggest that long term swimming is not an osteogenic mode of training. Female swimmers had no bone mass benefits despite long standing athletic training in our study. Our results are similar to those of Cassell et al (18) who studied in elite 7 to 9 year old female athletes. Grimsteen et al (30) also found that children 10-16 yr of age who participate in high impact sports such as gymnastics have higher BMD than children participating in swimming training.

In one cross-sectional study indicate that heavy musculoskeletal loading produces positive adaptative responses in the growing skeleton at specific skeletal sites subjected to repetitive impact loading (31). Our study supports finding that weight-bearing activity is necessary to produce an increase in bone mass.

Despite swimmers consumed higher value of calcium on average of 1400 mg Ca than gymnasts, there was no statistical significant difference between the two athletic groups Both the gymnasts and swimmers in the present study reported consuming equal or more than 1200 mg/day recommended dietary allowance for calcium. In the current study, the relationship between calcium intake and QUS parameters of calcaneus was not significant for both groups. Matkovic et al (32) carried out calcium balance studies with adolescent and suggested that calcium intake for this group could be as high as 1800 mg/day for optimal attainment of peak bone mass. One review of the literature has concluded that there was a positive relationship between calcium intake and bone mass (33). In one study it has been shown that that calcium intake and physical activity seemed to contribute little to the variation in bone density. They found an increasing trend in all parameters with pubertal stage and age (34).

In conclusion; The primary findings of this investigation was that calcaneal bone density was greater in preadolescent female gymnasts compared with age matched swimmers. Nevertheless, our results in prepubertal athletes suggested a useful role for QUS in assessment of bone status.

Osteoporosis is a major health program in the world today. Low bone mineral density is an important risk factor for osteoporosis and related fractures (35,36). It has been demonstrated that peak skeletal mass is a determinant of osteoporosis (37,38,). Current strategies with regard to the prevention of osteoporosis focus on maximizing bone mass early in life during periods of growth and minimizing losses later in life. Prevention techniques aimed at increasing peak bone mass, should begin as early as possible. Two factors, exercise and nutrition, which can be controlled, play an important role in achieving and maintaining peak bone mass. The importance of physical activity in the development and maintenance of BMD is widely accepted. Cross-sectional studies have reported higher BMDs in athlete than in sedentary controls (39).

Prepubertal years are a particularly important time for BMD. Physical activities, especially weight-bearing exercises and calcium intake are important for bone accumulation during

the pubertal growth spurt (40,41) Active lifestyle and increased physical exercise to improve muscular strength should be important to avoid the osteoporosis (42).

We recommend participating in sports activities during the pubescent years for maximizing the peak bone mass and thus preventing osteoporosis and related fractures in later life.

We conclude that physical activity in childhood could be an important factor in bone mineral acquisition in prepubertal girls; gymnastics can induce bone strain during a long –standing athletic training while swimming can't; but this remains debetable that is why longitudinal studies are needed to confirm our cross-sectional observations.

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